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AN

INVESTIGATION OF THE MOVEMENTS

OF

TEIGNMOUTH BAR.

BY

T. SPRATT, C.B., F.G.S.,

CAPTAIN, ROYAL NAVY.

LONDON:—JOHN WEALE.

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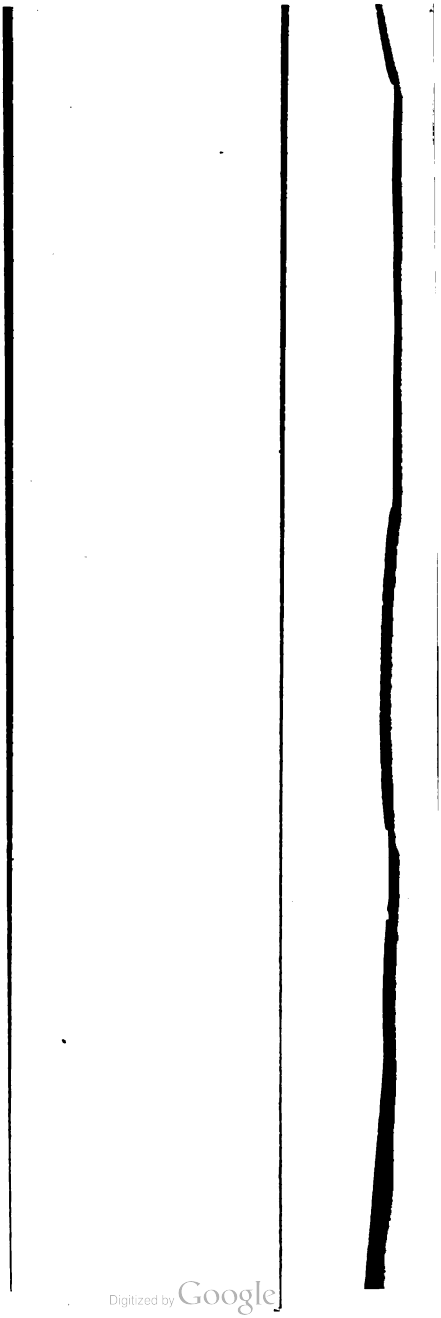
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CAPTAIN, ROYAL NAVY.

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1856.

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TO

HIS EXCELLENCY

SIR WILLIAM REID, K.C.B., ETC.,

GOVERNOR OF MALTA,

Who early drew attention to the Lateral Movements of some of our Coast Beaches, this extension of the inquiry is Dedicated, with respect and admiration for his many other labours in the investigation of Nature's Laws, and his endeavours to render them practically available,

By his obliged and faithful servant,

T. SPRATT,

CAPTAIN, R.N.

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AN

INVESTIGATION OF THE MOVEMENTS

OF

TEIGNMOUTH BAR.

Having resided at the town of Teignmouth, in Devonshire, during the years 1848, 1849, and 1850, my attention was drawn to the movements of the Bar sands; and being also a native of the place, my early years were spent upon its shore. This stamped upon my mind a recollection of certain appearances of the Bar sands from my boyhood days. I was in consequence greatly struck, in the spring of 1850, with the exact re-appearance of the Bar and banks forming it, to what had existed in the summer of 1836, when, being for a short time on half-pay, I amused myself by making a survey of the Harbour, which was published by the Admiralty.

Impressed with the fact of this reappearance, it soon occurred to me that other forms and positions of the banks had also been repeated within my own memory.

As a natural consequence, this evident repeti-

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tion of similar conditions seemed to result from some constant law of movement; and considering also that tides and winds, when viewed over a period of time, must have certain general effects, I was disposed to believe the law might be solved.

Reasoning, then, upon the influence of tides and winds, as agents of transport to the sands of a shore, and their general direction at the mouth of the Teign, it was soon evident to me that this law of movement was a rotatory one; that is, a rotation of position, variable in amount as to time, but certain in direction and ultimate tendency.

I shall now proceed to point out two or three of those repetitions of the moving banks or bar, which many of the inhabitants as well as myself have become familiar with, when left dry at low water, without being able to give either the date of each return, or of the time usually required to complete the rotation and repetition. But it seems to be a period varying between three and five years, and even longer.

The first well-known condition of the Bar which I shall point out, is when a long hook of coarse sand or shingle, dry at low water spring tides, extends from the Ness Point for nearly half a mile in length, as in 1848. Its position and form are shown in Plan No. 1.

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When this hook is thus fully developed the Denn Point is much reduced in its general height, and then affords poor shelter to the Shaldon side of the harbour during easterly gales upon high tides. And the entrance to the harbour being round the extremity of this long hook, and the channel long and tedious, its navigation is then difficult and intricate.

The next condition of the Bar and entrance is when there exists a passage close to the Ness Point, and then consequently leading fair into the harbour. The position of the old shingle hook is then replaced by one long bank, or by two banks called the Poles, now lying partly in the fairway of the former eastern channel: see Plan No. 2.

A third well-known condition is when the inner of these two banks, called the Inner Pole, has nearly or quite reached the Denn beach in front of the lighthouse; when it generally assumes when dry, at half tides, the form of a horse-shoe, by which name it is commonly designated.

When this occurs, the entrance is then by what is termed the middle channel; being intermediate between the eastern and western positions before described; through the reappearance or re-formation of a portion of the shingle

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hook, extending from the Ness Point: see Plan No. 3.

I will now proceed to show that these positions follow each other, and that the second and third conditions of the Bar result from the pre-existence of the first; which change I believe to be generally effected in the following manner.

Supposing the hook to have been completed to the extent shown in plan 1, by the accumulation of most of the material liable to shift and rotate; this condition may no doubt remain so for some months, viz. until an easterly or on-shore gale occurs, particularly if completed at the beginning of summer. It is then that the first grand change in the condition is most likely to be effected, viz. by the sudden change of the entrance from its eastern position, to its western, close to the Ness Point; and no doubt effected in the following manner, viz. by the heavy surf which rolls on to the coast during a gale, upon flood tide especially, and then throwing forward the extremity of the hook, so as to partially block up, or greatly contract, the channel or former embouchure.

The ebb, as soon as it makes out, being thus checked at its old exit by a contracted or blocked channel and *opposing sea together*, will be forced to escape over that part of the hook where it is

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first directed, and where the sea is least in opposition; that is, at the neck of the hook at its junction with the Ness Point. A cutting down of the bank at this part necessarily follows, and a new channel is thus in a tide or two opened there. The result of which is, the insulation of the shingle hook, and the placing of it *inside of the greatest action of* all future ebb and flood tides, instead of outside as before. This is a change of material importance in respect to its future movements, and the cycloidal rotation which follows.

I feel convinced that the blocking up of the eastern channel when the hook is very long may be effected in one or two tides, if a heavy gale from the eastward continues over that time. For, on consideration, it will be seen that the tendency of the Bar banks is always greater towards a return to the Denn shore, than to seaward, as many suppose.

The reason being this, that as the chief agents of transport of the particles composing them, are the lifting and moving power of a surf and tide together, an off-shore wind cannot here produce an off-shore surf to unite with an ebb tide, so to form two forces acting in that direction, —that is, to seaward.

But as the heaviest seas capable of lifting and

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moving the sands of this Bar, can only occur with an on-shore wind and sea, *the two forces of an ebb tide and high sea are consequently on those occasions in antagonism.* And these forces never being in unison in the off-shore direction as before shown, the sands of such a Bar cannot easily be dispersed to seawards, until so communicated as to be almost held in suspension. But if the locality is exposed to prevailing lateral winds and seas, a dispersion in a lateral or along-shore direction will in those localities necessarily occur, and partially outbalance the indraught produced by the adjacent estuary tending to hold those shifting sands within certain limits of its entrance.

Then, considering how powerfully the two forces of an on-shore surf and flowing tide are, when acting in unison, in the on-shore direction, it will be easily perceived how great may be the amount of the movement of the sands of a Bar in that direction during a few tides with a heavy on-shore gale; more particularly where the ebb is not fed by any large body of fresh water, to counterbalance its permanent effects, as at Teignmouth.

Although Teignmouth is not exposed to the prevailing westerly gales, yet we must look even upon these, although off-shore winds here, as

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also favouring the flood and opposing the ebb tides. Because the swell which is forced up the British Channel before those winds, as soon as it has power to extend laterally by any expansion of the coast into a lateral bay, such as that from the Start Point, it will be so expanded in some localities as to become, *and to produce an action, almost, if not quite opposite to the originating cause.*

Thus, with an off-shore wind, an on-shore action of the surf may be the result in many localities on our coast; such as no doubt occurs at Teignmouth Bar during a south-west, westerly, or north-west gale; when, notwithstanding that we have immediately without the Bar a sea breaking off the shore, yet the British Channel swell will produce a much heavier surf breaking upon the Bar and shore, in opposition to the wind and ebb, and in favour of the flood.

It will therefore be perceived, from what has been said respecting the on-shore tendency of the sands by the united action of surf and flood tides together, that when the extremity of the long sandy hook has been thrown forward by it, *and the inside of the bank is thus relieved from the greatest strength of the ebb, the balance in favour of the on-shore tendency of the sands will be greatly increased.*

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The bank will thus gradually advance towards the Denn beach; and, as the *extremity* of the hook by its previous advance will also then be the part most relieved from the effects of the ebb, in consequence of the main force of the stream now making its exit at the new entrance near the Ness Point, its progress, under the continuing influence of surf and flood, and diminished influence of the ebb, will be quickest, so as eventually to cause the previously isolated hook to be divided into two banks, as in the plan (No. 2), showing the second well-known condition of the Bar. And the relative positions of these two banks will in a short time be the same as represented in my survey of the harbour in 1836, and also as they appeared in the beginning of the year 1850.

A few months' interval of time may bring about the third condition, which is the same as appeared in September of the same year, when the "Horse Shoe Pole" was again the peculiar and well-known form of that Pole bank, when it has reached that position; the two horns of the shoe being the evident result and indication of the *preponderating indraught on, or along*, that shore, towards the mouth of that river.

In January, 1851, I re-examined their positions by a proper survey, and found that the further

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advance of these two banks in this short period of four winter months was at least 150 feet *nearer the shore*, in the direction indicated by the arrows on the large plan, upon which the relative positions and changes of the banks are shown, to illustrate more clearly the law of movement. And at the period last mentioned, the horse-shoe form of the inner Pole had disappeared, the bank having now become merely a projection or point, dry at half-tide by the heaping up of the sands and shingle. One dry bank or one island alone remained; but the other feature of the Bar banks was rapidly forming,—nearly one-third of the complete length of the hook was now dry at low water spring tides.

During the interval over which these observations were made, the "Denn Point," which was comparatively low when the Ness hook was complete, had fluctuated considerably, according as the gravels had either accumulated upon it or had been again washed off, by the rotatory or cycloidal movement of the sand banks; the limits of which and the full cause has yet to be explained. But before doing so I shall draw attention to the accompanying diagram, or section of the Denn Point, to show the portion of it which seems exclusively subject to the shift, or to be included in the rotation.

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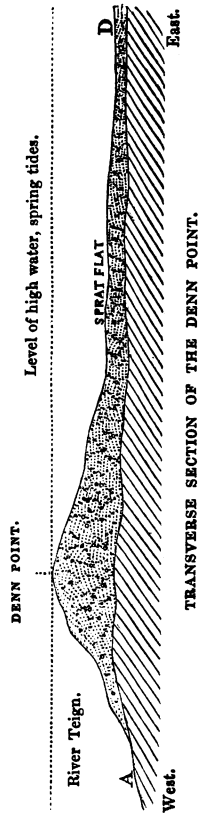
A D is a transverse section of the extremity of the Denn Point, in which there are shown two strata or beds of deposit.

The upper bed, distinguished by dots, is composed of loose gravel and sand, whilst the lower, denoted by diagonal lines, is a somewhat hard bed of shingle, mud, and sand, which, like the "salty flat," a bank within the harbour, seems to resist the friction of the tides, thus forming a bed or basement to the overlying drift sands, composing the upper part of the Point.



We must therefore regard this upper portion of the Denn Point as a sort of quicksand or moving bank similar to the Bar banks—it being in truth such, under certain conditions and circumstances that occasionally occur, namely during a heavy sea upon spring tides, when the Point from a few yards south of the lighthouse is entirely overflowed, and in great agitation by the on-rolling surf and flowing tide.

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Now, re-considering the movements and causes of change in the particles composing the sand-banks and Denn Point, we find that they must result from the two general causes: 1st, the effect of heavy seas rolling on or along them,—and 2nd, the action of strong tides scouring certain parts of the adjacent shore and sides of the banks; the former of these causes of course producing the most rapid changes, whilst the latter even alone continues a slow but nevertheless certain amount of movement in a given time.

Examining, then, into the state of the tides at the mouth of this estuary, I find them to be thus:—that the ebb is seldom strong on the beach outside of the Denn Point, except at its extremity. But throughout the whole tide, as might be expected from the form of the coast, the ebb makes directly out of the estuary along the Ness Point shore, with its greatest velocity and force, and consequently keeps up a good scour along that shore during the whole six hours' ebb.

Then, next examining the state of the flood-tide and its influences, I find that during the first half, of three hours' duration, the strength of the stream during this time is also on that shore. But, as the estuary has then only a few narrow channels drawing from the outside tidal wave during the greater portion of the time, the in-

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ward or back drift is of no consideration. Also, as another reason, no heavy sea can then reach this shore till the tide is higher, as the Bar banks break the sea during this period.

During the last three hours of a flood, it runs with great force into the harbour, as the whole estuary for two or three miles up is overflowed and drawing from without.

But then, the whole strength of the stream is along the Denn shore, and of course keeping up a considerable inward scour along it during this interval; so that, taking the time of a whole tide in view, we have then a *strong scour out on the Ness side for six hours; counteracted by only three hours of a slack portion of the inflowing tide.*

And on the opposite or Denn shore we have three hours of the strongest part of the flood, producing a great inward drift there, and counteracted by no important drift or tidal scour during any part of the ebb. The particles composing the banks and beach on this side have therefore a predominating tendency to travel on to the extremity of the Point. For in this part of the investigation of tidal influence alone, it is the velocity or *force* of a tide, more than its *duration*, which becomes the more important moving agent.

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By the contraction of the channel off the Denn Point the stream abreast of it is of course always strong, so that the particles of sand or gravel which reach it are either carried round, to be deposited at its back on the river side, or are carried across by the force of the stream over to the Shaldon creek and beach. Now, as the ebb, as soon as it makes, strikes directly down the Shaldon shore, and directly against the extremity of the Denn Point with its full strength, much of the matter accumulated there during the flood will be swept back again into the stream, which now having a direction towards the Ness Point, and its velocity keeping up a continued scour on that shore, all the ebb will eventually reach that Point. But, as the ebb there meets with the along-shore tide, or slack water, its strength and direction is suddenly checked, so that a deposition of the heavier material brought out will necessarily take place there.

Thus, a spit or tongue of gravel and sand gradually grows out from the Ness Point, curving slightly at first, till the along-shore and river tides balance each other.

By this progressive advancement of the shingle tongue, the entrance of the harbour is pushed forward from south to north, but at a fluctuating rate, according to the prevalence and force of

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winds, and the strength of tides operating with them, until all the sands liable to rotate are accumulated upon it, so to change the position of the entrance from what is termed its western one to the eastern, at the end of the completed shingle hook or tongue, nearly four cables' length from the former, as shown in Plate I.

But as the advance is not regular, we may have the channel almost stationary, for a long time, at any intermediate position, such as what is termed the middle channel, or advancing so slowly under the simple action of the tides alone, as to be hardly perceptible, till a strong gale, or swell on or along the shore, produces an increased development of the hook; when the common belief is that this increase of the hook has been derived from the sands thrown in from *seawards* by the previous gale, instead of the fact of having been brought *outwards* from the Denn Point and Shaldon shore, etc., by the gale having merely quickened the rotation.

Thus the rotatory movement of the particles forming the shifting Bar is made evident by showing, first, the great tendency of the sands composing it to be thrown on and along the Denn beach by the on-shore seas and floods together; and next, by the predominating force and scour of the returning ebb, being along the

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opposite side of the entrance; each movement representing large segments of a cycloid, as shown by the arrows in Plan 4.

It will thus be seen that in any consideration of the shifts and changes of the Bar banks here, the "Denn Point" must be coupled with them, for the conditions of the one are intimately connected with the condition of the other; their composition not only being exactly similar, but both are at times brought into the condition of a quicksand; the Bar being truly so when covered at half tide, and the Denn point also at the top of springs, when the sea is much agitated by any on-shore gale.

Therefore, in such an investigation as the present, every condition of the one or the other, and every natural influence, great or small, which may effect those conditions, must be fully considered and understood before any plan to obviate them can be proposed.

Now, as the Denn Point is open from about south to east by compass, a gale from any intermediate point causes a heavy sea to beat over it at high tides. The harbour is then greatly exposed by the overflow of this natural breakwater, and these gales may either seriously impair this Point, or they may temporarily improve its condition, depending upon the dura-

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tion of the gale and the state of the tides at the time.

Thus a strong gale direct on the shore, if happening during neap tides, and over a greater amount of flood than ebb, will greatly add to it by the sands thrown in from the Pole banks. The point will also be generally increased and improved by a prevalence of light easterly winds, because the ripple constantly kept up by it, and having a constant direction towards the Point, will cause an accumulation there of the travelling particles.

We must now inquire into the chief causes of degradation and damage to the Denn Point.

And it will easily be understood that a great degradation of the *extremity of the Point* may be effected by strong westerly and north-westerly winds acting with an ebb tide; since, the ripple and tide acting together, against a steep and loosely piled bank of sand and shingle, will so undermine it as to cause tons of the sands to fall into the stream every tide, which for the reasons before shown will of course be carried out to the Ness point to increase the tongue growing from it.

This last fact explains why the pilots are obliged to be so watchful of the entrance during a strong north-west or west gale, but who look

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rather to the freshets from the upper part of the river, or to local drifts from without as the cause, instead of the true reason, through the operation going on under the somewhat quiet conditions of an off-shore wind. I shall hereafter show that the freshets of the river have comparatively little to do with the re-supply of material to the Bar.

But the most damaging condition to the Denn Point are those gales which blow from the eastward; for, although the fetch of the sea is not great, yet the surf having a direction along the shore, it becomes then a powerful agent of transport to the sands thus agitated and lifted by the surf.

And if such a gale happens upon a high spring tide, the whole point is liable to be shorn down two or three feet, by the rolling surf and flowing tide together, during its quicksand condition at that time. And as these sands will fall into deep water, and a quieter sea under the lee of the Point, the bank will be piled up steep on the river side instead of the material being much spread out into the bed of the stream. The ebb then making before the point has been long subject to this joint effect of sea and tide together, it will then in part check the full force of the rollers and divert the agitated sands more towards the extremity of the Point or into the

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stream off it, so as finally to reach the Ness hook, yet only to return again in the course of a certain but fluctuating rotation between the Bar, the Denn Point, and Shaldon beach.

It therefore becomes evident, that if the rotatory movement can by any means be checked, and the interchange of material between the Denn Point and Bar be prevented, by holding fast the former when in its best condition as a breakwater, that we shall also retain the best condition of the Bar, the position of the entrance more constant, and probably deeper also.

To effect this, then, we must combat the two great causes of the degradation and destruction of the Denn Point; that is, by preventing the sea from ever overflowing it, as well as preventing any undermining of the extremity of the Point on the river side.

There are two great objections to any *front wall;* first, the necessity of its being a very solid and costly piece of masonry, and next, that such a wall would assist the travel of the sands with a lateral sea, and be liable to have its base undermined by it also. But by simply converting the point into a sort of artificial hook, by backing it at a proper elevation on the river side,— that is, fully 4 or 5 feet above the highest tides, and carrying out a more substantial curved

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groyne from its extremity, as shown in the large plan, we shall not only grasp, but permanently hold these rotating sands, so that the Pole banks will after a time be joined to the Denn as dry land, never to return again. And as this backing and groyne will never be exposed to a direct sea, it need not be of so substantial a character as ordinary sea-piers or breakwaters, because the immediate accumulation of the sands against them (if my theory is correct) will form a beach to receive the surf instead of the masonry.

Thus three important advantages will be the result. First, the reclaiming a valuable piece of land from the sea, viz. the whole of the Denn Point, with the Pole Sands. Second, the forming a permanent breakwater to the harbour at comparatively small cost, since the wall, as a mere backing on the river side, need not be more than from 2 feet 6 inches to 3 feet thick; as nature will effect most, and become primary in its effects, though secondary in its cause. Thirdly, the entrance will be limited to a smaller range in proportion to the extension of the groyne, and the amount of the rotating sands it can cut off.

Now, taking an estimate of the cost of such a structure from the bold works and groynes along the coast in the vicinity, and in connection with the South Devon Railway, I find that

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£3000 would be the outside of such a piece of engineering work as I have marked out on the plan; which, setting aside all consideration of the benefit to result to the Harbour and Bar, would in time amply be repaid by the value of the land reclaimed from the sea, and added to one of the most beautiful promenades on the south coast of England.

But the more important point connected with this inquiry is touching the *diminution* or *removal* of a Bar to a valuable harbour; for it will easily be perceived that the establishment of a law of movement at one of our bar harbours will lead to the impression *that the law bears upon many others;* and although, no doubt, modified at each by peculiar local features and conditions, yet it may, nevertheless, be clearly investigated by a due attention to the *direction*, *duration*, and locality of *greatest strength*, of any part of the flood and ebb tides, coupled with some observations on the position and appearances of the banks when dry at low water, or by repeated surveys.

Before concluding, some notice must be taken of the origin of the Bar sands at Teignmouth. And having before stated that I was of opinion the Bar receives little accumulation from the wash of the River Teign, I will here give my reasons.

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After a careful examination, I am convinced that the Teign, when it reaches the lower part of its estuary, brings down little else than mud and fine sand; and that the *débris* from Dartmoor and the hills bordering the upper branches of the Teign, are deposited in the level channels of the upper part of the estuary; for a fragment of granite, which is the composition of those hills, is not easily to be found amongst the sands and gravels of the Bar. The chief origin of these banks is, unquestionably, the "New Red Sandstone Cliffs," overhanging the estuary or extending along the coast. Its conglomerates have hitherto been, no doubt, a fertile source for re-supplying gravel and shingle to the Bar and Beach; and as granite is no component part of their strata, we can thus conclude with certainty that the *débris* of Dartmoor does not reach the mouth of the estuary, except in a very comminuted condition, so as soon to be easily transported beyond by the further reduction and friction under the agitation and rotation it will now be subject to.

As the South Devon Railway now protects the cliffs on the east side of the harbour of Teignmouth, the main source for the re-supply of gravel will, for the future, be chiefly from the western cliffs of the Ness and towards Babbicomb

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Bay; which could hereafter be held in check by a simple groyne behind the Ness Point, so that eventually there will be little or no material to rotate as a bar if the groyne I propose should extend from the Denn Point is carried out sufficiently far: which probably would be best constructed of unhewn blocks, and progressively advanced, with the accumulation of the sands and gravels against it.

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On the Mode of Investigating the Movements of a Bar.

To facilitate the investigation by a landsman or civil engineer, I venture to give, with all due diffidence, some ideas upon this head, and upon their general movements, which I think will generally be found to be cycloidal, for, if we only take into view the effect of the daily ebb and flow alone as a moving agent, and also that the ebb and flood are seldom of precisely the *same direction, strength, and duration over the same locality* in the mouths of estuaries—by reason of projections or banks causing eddies, or diverting their *return effects; this cross action* must eventually cause some change of position in the materials of those points or banks liable to shift, instead of being merely a backward and forward movement on the same ground. And, although such movements may be small in amount during each tide, yet, occurring as it must four times a day, the effective progress under this *cross action* will after a lengthened period be evident, and to an amount proportional to the preponderance of one tide, aided by prevalent winds, over another, and the deviation in direction of the two tides.

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It must be evident, therefore, that until such law is understood at any locality, no engineering work can be carried on there to effect an improvement in the Bar or entrance; but when understood, a simple plan may suggest itself, by which much benefit may result, at small engineering cost, as in the case for that proposed for Teignmouth, where an eminent engineer once proposed to effect by a work of £20,000 cost, what may be done for less than a quarter of that amount. And if at any Bar there is known to be a repetition in the form of any of its banks, there is good reason then to believe that some such law exists there.

The investigation of this law may be facilitated, by adopting some such plan as that shown in Plate 4, to illustrate the *duration and force of the two tides* at any locality in the vicinity of a moving Bar. Thus, if by the *thickness* of an arrow it denotes the comparative strength at any time of tide, and by its *length* the comparative duration, we at once perceive where the predominating movements are,—that is, where the velocity or scour is most *constant* and *strongest*, where counterbalanced, and where the outward and returning forces have the same, or an *angular* direction; for it is evident that the *greatest* velocity or *force*, more than the longest duration, will in most cases produce the greatest amount

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of movement,—that is, where the material is of a certain gravity.

Thus the hidden travel of material along the bottom, will be indicated in great part by a registry of the *superficial force and direction* of a stream during the two tides; and, by following the thickest arrows indicative of the greatest forces, the eye at once sees the general line of movement. But the influence of winds must next be considered in conjunction with its tidal effects.

This investigation has led me to understand that there may be two species of rotation of the sands at the mouth of a harbour or within an estuary or river. For the particles may rotate round a *deep centre*, as at Teignmouth, or they may rotate round a raised centre or *bank*, as in part at Exmouth, and no doubt many other localities, so as merely to alter or advance alternately or permanently some of its projections.

At Exmouth also, as before alluded to, I have clearly made out the wheeling or cycloidal movement, as being truly applicable to its banks; but where, from the very fine quality of the sands or gravel forming its banks (owing to the "New Red Sandstone" cliffs adjacent, from whence the sands are derived, being wholly composed *of very fine red sand*), as well as from the position and direction of several *ledges of rocks in the channel*

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acting as diverting groynes, the rotating particles *are thrown across the channel and back upon the "Pole Bank,"* from the east side of the entrance, but merely to revolve round it again; for, the rotating particles fluctuating between the Warren Point, Exmouth beach, and Pole bank, not being heavy enough to deposit against these natural groynes when carried thus far, or to reach the mouth of the harbour by the Exmouth shore, so as to form a hook there as at Teignmouth, are thrown across the channel before they can arrive at the slack water at its mouth.

Thus the estuary of the Ex has a constant entrance; and, in an engineering point of view, the condition of this entrance and its cause are as instructive as that of Teignmouth.

In both, a cycloidal movement of the sands is evident, but modified in results, effecting the entrance by peculiar local conditions; and the evident way to prevent the fluctuations of the sands between the Warren Point, Exmouth beach, and Pole bank is to *check the rotation* by groyne across the line of the return movement just as at Teignmouth, so as to cause the sands to accumulate against it, and thus to raise a bank or beach there as a permanent breakwater, both to the estuary and town of Exmouth.

The construction of such a groyne was suggested some years ago, so to shelter the estuary

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of the Ex, which has become much exposed of late years by the rapid destruction of the Warren Point, which formerly extended out to the Cheeks Rock ; and as a substitute for this lost portion of the Warren, a groyne was the natural suggestion.

And had the Civil Engineer to the Exmouth property understood the movement of the sands, he would, I humbly think, have preferred the construction of this groyne as a mere backing to check the movement and grasp the sands, in preference to the costly sea-wall that was recently built in front of the town of Exmouth to prevent the encroachment of the sea there, since its exposure by the waste of the Warren Point: for the groyne at the end of the Warren would have been of certain and permanent benefit as a breakwater, not only to the property at Exmouth, but to the harbour also.

The importance as well as interest of further prosecuting such an inquiry as this cannot be questioned; for our commercial trade being now in competition with the whole world, every facility to commerce is necessary, by facilitating the entrance to, as well as the improvement of, the numerous harbours which Nature has so bountifully given to us.

Malta, March, 1853.

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Concluding Chapter.

The substance of the previous pages was given in the year 1850 to the "Teignmouth Harbour Commission," who were then struggling to relieve the local trade from an unjust tax, levied annually by the town of Exeter.

But the paper in its present form was sent from Malta in March 1853, to a friend, either for communication at the next British Association, or for publication through some other channel. My absence from England, and the death of my lamented friend, prevented my recovering the paper until a few weeks since.

This delay in its publication, however, enables me to add greatly to the original value of the matter contained, by the experience gained during the five years' interval since 1850, having fully confirmed the correctness of my views and ideas, then advanced upon a brief inquiry only: viz. *that the movements of the Bar sands were governed by a law, instead of being wholly fortuitous; and that the movement might in great part, if not wholly, be held in check by a simple and comparatively inexpensive work.*

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It was therefore most satisfactory to find, upon a recent brief visit to Teignmouth, that the Bar was again nearly in what, for convenience of description, I have called the first condition, and as shown in Plan 1. That is, with the sandy hook almost complete, and in fact, just as I had observed the state of the Bar and entrance in the year 1848, when, as now, the entrance was in consequence in its worst state.

Thus the complete return to similar conditions seems to have taken, in this instance, above seven years. But this must depend much upon the *strength of certain, or prevailing winds at particular* times of tides during the intervening seasons; so that it may no doubt be sometimes effected in a much shorter period.

Moreover the cycloidal rotation may sometimes be effected *over a smaller area* than that shown on the large plan, through the sudden reopening of the western channel near the Ness, after a gale, when the sandy hook is only partially completed. For there is a tendency generally to keep the hook somewhat lower nearer the Ness, by reason of the ebb always making direct for the neck of hook; and from the lighter particles of sand brought out, being then carried beyond—so that a channel for small craft and boats often exists close to the Ness.

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Much of the finer or lighter particles composing the sand-banks may also be thus continually rotating within a very small area by returning or advancing from the Bar along the Sprat flat (which is generally composed of the finest particles of the moving sands), instead of being united with the Denn Point during the revolution.

These fluctuations in the rotation may also, as will be evident on consideration, prevent at times the *exact forms* from reappearing, although the banks may have returned to the exact positions shown in Plans 2 and 3; because not having the same quantities of material.

This however is not the real point of importance in the investigation, and is merely referred to, so to guide the inquirer *from partial to general results*, instead of dwelling too much upon accidental effects.

For it is the fact of there being a cycloidal movement, a rotation of the sands and gravels, instead of a fortuitous gathering of them without a law, that constitutes the importance of the investigation. And thus upon an understanding of the law, to be able to see clearly the effects of any engineering work; and so to remove a Bar, or improve an entrance with the most certainty and economy.

I shall now close my remarks with some ex-

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tracts from a letter I have recently received from Mr. Mackenzie, the clerk to the Teignmouth Harbour Commission, to whom I had applied for some information respecting the movements of the Bar between 1850 and the present time.

"*Teignmouth, Feb.* 28, 1856.

"I have much pleasure in informing you of what has been done since your letter of the 1st of September, 1850, about the sand-banks at the mouth of the Harbour.

"We gave notice for a Bill in Parliament to amend our own Harbour Act; to extend our powers; and to abolish the Exeter town dues, or have them applied towards the improvement of our Harbour.

"To support the latter part of our case, I took advantage of your labours, and had plans and estimates prepared for carrying out your view. And in order to test your project, I obtained the aid of a Mr. Bell, an Assisting Engineer of the South Devon Railway, who took a great interest in the subject. He closely watched the state of the whole entrance and all the sand-banks for many months, and noted the numerous alterations with the state of the tides and the wind. I send you four plans showing the result of his observations.

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"These from actual observations I can verify: and they prove the accuracy of your ideas in every point I believe, so far at least as I am able to judge.

"Mr. Bell was unfortunately removed from the town, and unable to continue his observations, which I much regret; but I have taken some trouble myself, once a month at least, to watch and examine at the lowest spring tide the state of the several banks; and I can testify that the same rotatory motion exists; and that with great regularity, taking the averages."

I take this opportunity of thanking my friend Mr. Mackenzie for his letter, and trust that at every harbour on our coast obstructed with a shifting Bar or moving sands, there may be found some one there possessing an equal interest in such an important inquiry: so to trace laws out of apparent irregularity and uncertainty, that eventually all our Bar movements may be understood; and then how to improve them, without working in comparative darkness in the attempt, as heretofore.

Malta, April 7th, 1856.

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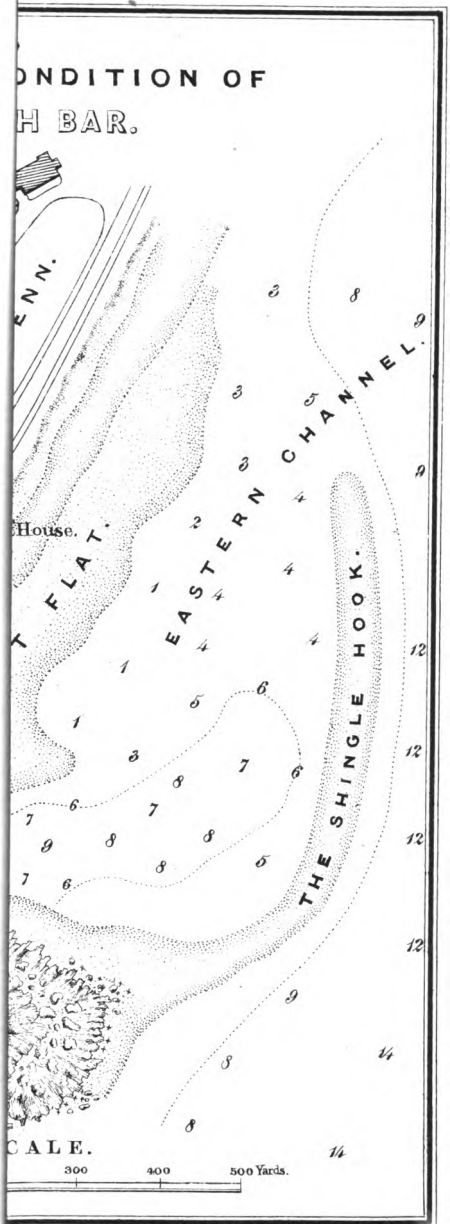

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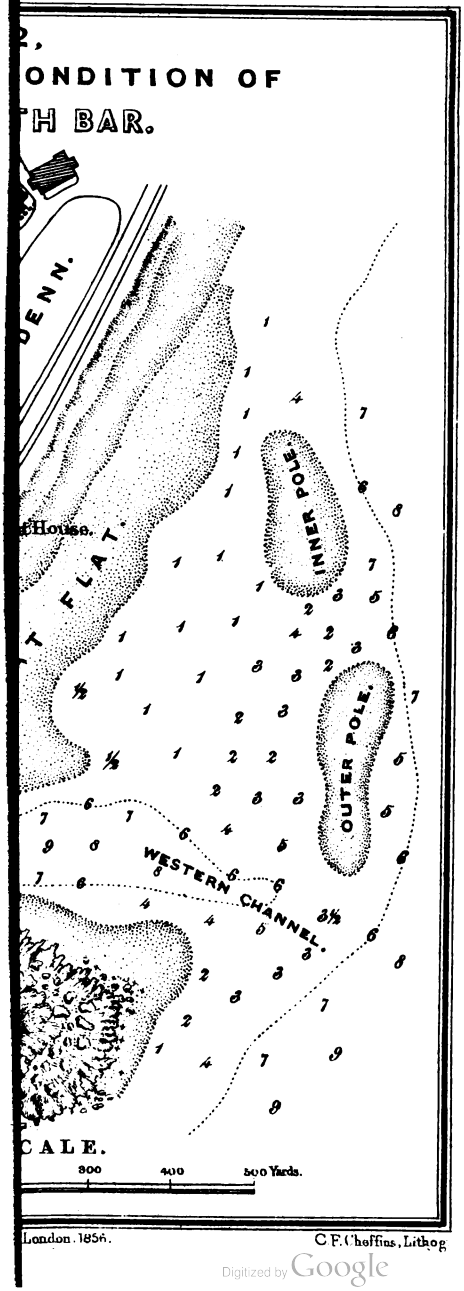

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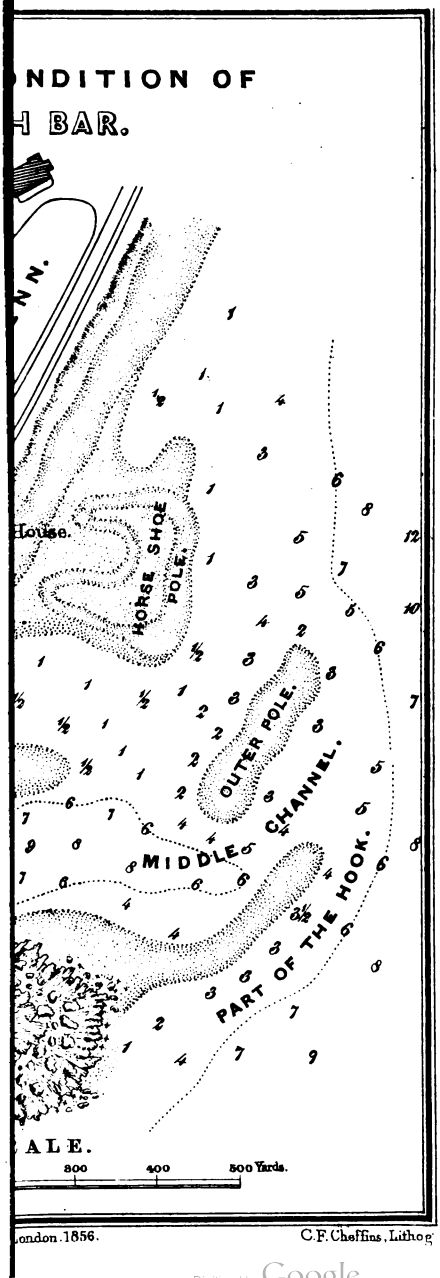

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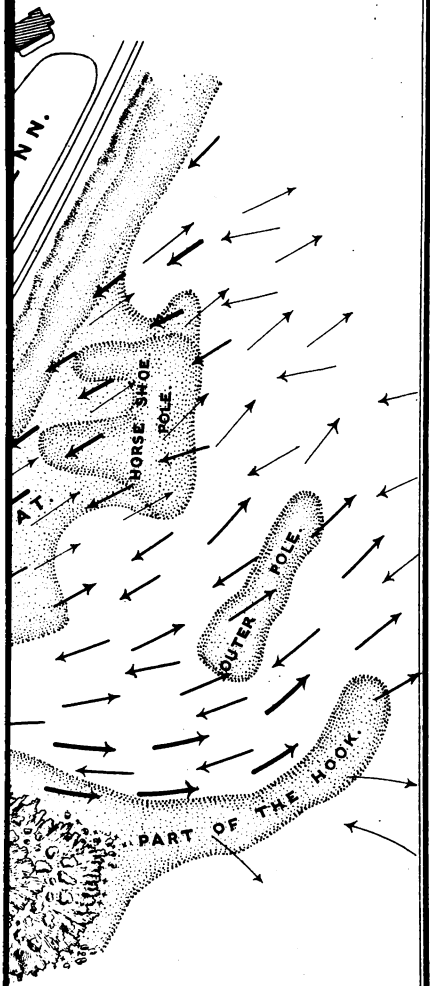

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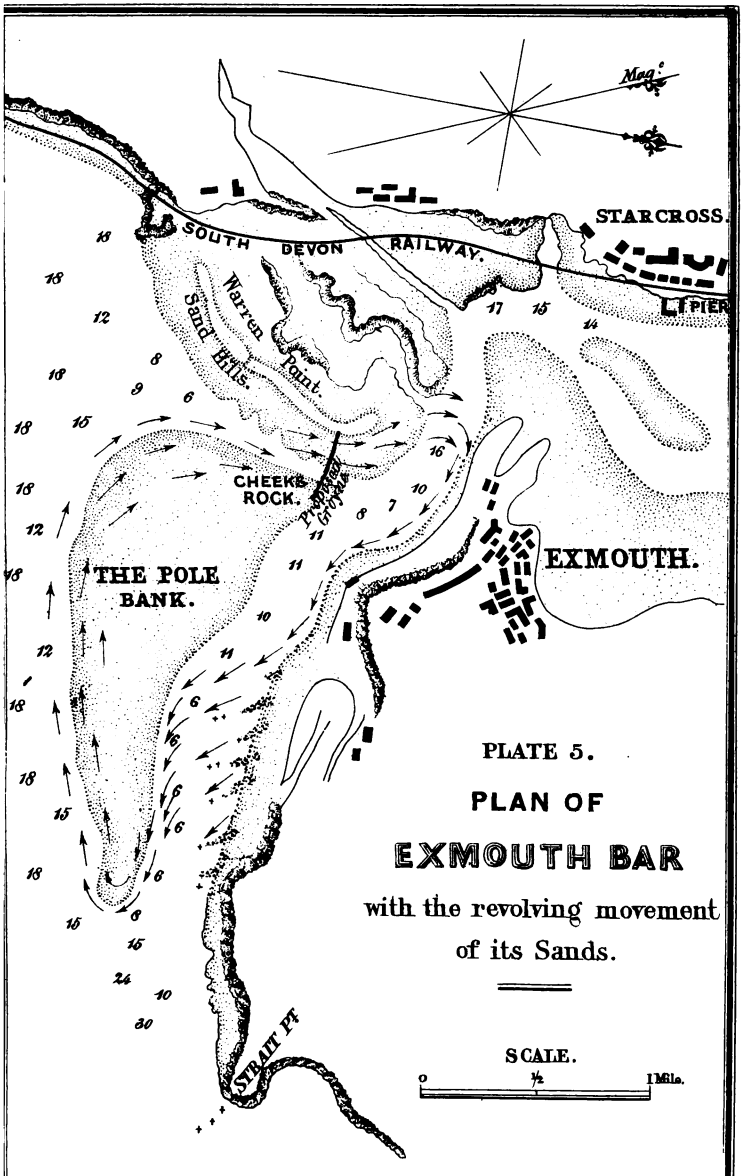

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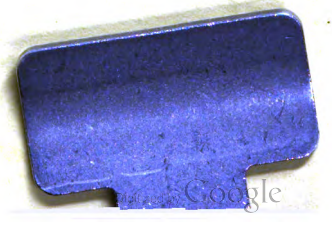
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